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DESCRIPTION

SURFACE ACOUSTIC WAVE DEVICE IAP5 Rec'd PCT/PTO 13 FEB 2006

Technical Field

The present invention relates to a surface acoustic wave device and more particularly to a surface acoustic wave device containing a surface acoustic wave element.

Background Art

Up to now, in a balanced-type SAW (surface acoustic wave) filter having an unbalanced-to-balanced-type filter of a first stage and a balanced-to-balanced-type filter of a second stage that are cascade-connected, a structure in which signal wirings for connecting the balanced terminals of the filters are disposed between the stages and a ground pad connected to the other terminal of an unbalanced terminal IDT (interdigital transducer, comb-shaped electrode) of the first stage is disposed between the signal wirings has been proposed.

Fig. 5 is a top view of a substrate contained in a surface acoustic wave device of a related example. The substrate 1210 is a $LiTaO_3$ single crystal substrate and, on its main surface 1212, as shown in Fig. 5, a metal film of a fixed pattern is formed. That is, a balanced-type SAW filter, in which a longitudinal coupling resonator-type surface acoustic wave filter 1220 of the first stage and a longitudinal coupling resonator-type surface acoustic wave filter 1230 of the second stage are cascade-connected, a pad 1251 is used as an unbalanced terminal, and pads 1252 and 1253 are used as balanced terminals, is constituted. In an area enclosed by the filters 1220 and 1230 and wirings 1241 and 1242 for cascade-connecting the filters 1220 and 1230, a ground pad 1256 connected to an IDT 1223 including the unbalanced terminal 1251 is disposed (for example, see Patent Document 1).

Furthermore, in recent years, the requirement for having a

balanced-to-unbalanced conversion function or a so-called balun function contained in a surface acoustic wave filter used in the RF stage of a portable telephone has become strong. Lately, in particular, a longitudinal coupling resonator-type surface acoustic wave filter which can cope with a high-frequency wave and also can easily cope with a balanced-to-unbalanced conversion function has become main stream as a bandpass filter of the RF stage of a portable telephone.

The surface acoustic wave filter having a balanced-to-unbalanced conversion function is connected to a mixer IC (hereinafter, referred to as a balanced-type mixer IC) having a balanced or differential input and output. When this balanced-type mixer IC is used, the effect of noise is reduced and the output can be stabilized, and thus the surface acoustic wave filter has been often used for improvement of characteristics of portable telephones in recent years.

Regarding such a surface acoustic wave filter having a balanced-to-unbalanced conversion function contained, various structures can be considered and many of them have been proposed. These have merits and demerits according to each structure and are properly used in accordance with the intended uses and user's requirements. As one of them, there is one structure in which balanced terminals are connected to both terminals of one IDT.

For example, in Fig. 6, an element chip 30 of such a surface acoustic wave filter is schematically shown. The surface acoustic wave filter is made to have a balanced-to-unbalanced conversion function in such a way that both ends of the middle IDT 1 of a longitudinal coupling resonator-type surface acoustic wave filter element 6 containing three IDTs 1, 2, and 3 and two reflectors 4 and 5 are connected to balanced signal terminals 11 and 12, respectively and that one end of each of the left and right IDTs 2 and 3 is connected to an unbalanced signal terminal 13 through an IDT 7 of a surface

acoustic wave resonator 10 in which reflectors 8 and 9 are disposed on either side of the IDT 7. In the surface acoustic wave filter, the other ends of the IDTs 2 and 3 are connected to a ground terminal.

The element chip 30 is housed in a package which can be divided into an upper portion and a lower portion in the bottom-side portion. Fig. 7 shows the upper surface of the upper portion 33 of the package bottom portion 31 in which the element chip 30 is mounted, Fig. 8 shows the upper surface of the lower portion 36 of the package bottom portion 31, and Fig. 9 shows the lower surface (bottom surface of the package) of the lower portion 36 of the package bottom portion 31.

As shown in Fig. 7, wiring patterns (lands) 42 to 45 are exposed in the die attachment portion 41 of the upper portion 33 of the package bottom portion 31 and bump-connected to the terminals (pads) of the element chip 30 by a bump 39 shown by a white circle in Figs. 6 and 7. In Fig. 7, via holes 46 and 47 shown by black circles pass through the upper portion 33 of the package bottom portion 31 and the wiring patterns 45 and 44 and wiring patterns 61 and 63 of the lower portion 36 shown in Fig. 8 are connected. Among external terminals shown in Fig. 9, the right middle external terminal 56 is an unbalanced signal terminal, the left upper and lower external terminals 52 and 53 are balanced signal terminals, and the other external terminals 54 and 55 are ground terminals. The external terminal 56 as an unbalanced signal terminal is connected to the unbalanced signal wiring pattern 42 through a castellation 48. The external terminals 52 and 53 as balanced signal terminals are connected to the balanced signal wiring patterns 43 and 44 through castellations 49 and 50.

Finally, corresponding to the disposition of the first and second balanced signal terminals (pads) 11 and 12 on the element chip 30 shown in Fig. 6, as shown in Fig. 7, in the flip-chip mounting package of the element chip 30, the first balanced signal terminal wiring

pattern (pad) 43 is formed in the middle of one side of the package, and the second balanced signal terminal wiring pattern (land) 44 is formed in the corner portion close to the first balanced signal terminal wiring pattern (land) 43. In the element chip 30, a signal line 1a for connecting one end of the IDT 1 and a first balanced signal terminal 11 and a signal line 1b for connecting the other end of the balanced ITD 1 and a second balanced signal terminal 12 become unsymmetrical and, when they are unaltered as they are, the balancing deteriorates. Then, as shown in Fig. 9, the external terminals 52 and 53 as the first and second balanced signal terminals are disposed so as to be symmetrical around the central axis of the package, and the balancing is adjusted by altering the path difference in the package between a signal line connected to the external terminal 52 as the first balanced signal terminal and a signal line connected to the external terminal 53 as the second balanced signal terminal (for example, Patent Document 2).

The surface acoustic wave filter package in Figs. 6 to 9 can be also used for mounting an element chip 60 having a structure in which two longitudinal coupling resonator-type surface acoustic wave filter elements 66 and 68 having three IDTs 66a, 66b, and 66c, and 68a, 68b, and 68c and two reflectors 66s and 66t, and 68s and 68t, respectively, as shown in Fig. 22. That is, the element chip 30 shown in Fig. 1 and the element chip 60 shown in Fig. 22 have the same external dimensions and the same terminal (pad) configuration.

In Patent Document 3, a float balanced-type surface acoustic wave filter in which the balancing is improved in such a way that two terminals extending on either side in the direction perpendicular to the surface acoustic wave propagation direction of the middle ITD of a longitudinal coupling resonator-type surface acoustic wave filter element are connected to balanced signal terminals, that IDTs on both sides are connected to unbalanced signal terminals by using two

unbalanced signal lines, and that one balanced signal line and one unbalanced signal line intersect in three dimensions through an insulating film is disclosed.

Patent Document 1: Japanese Unexamined Patent Application Publication No. 2002-300004

Patent Document 2: Japanese Unexamined Patent Application Publication No. 2002-271168

Patent Document 3: Japanese Unexamined Patent Application Publication No.2002-204243

As in the related example in Fig. 5, when two elements are cascade-connected and a ground pad is disposed between stages, since stray capacitance between the wiring for the cascade connection and the ground pad is large, there is a problem in that the insertion loss in the passband is large.

In consideration of such factors, it is a first object of the present invention to provide a surface acoustic wave device having two elements cascade-connected in which insertion loss in the passband can be reduced.

Furthermore, in a surface acoustic wave filter of a structure having a balanced-to-unbalanced conversion function contained by connecting balanced signal terminals to the terminals on both sides of one IDT by a method disclosed in Patent Document 2, since the structure of the package is complicated and specific, the package becomes limited to the element structure. Accordingly, for example, a surface acoustic wave filter 70 having the structure shown in Fig. 10 in which two longitudinal coupling resonator-type filter elements 71 and 72 having three IDTs 71a, 71b, and 71c, and 72a, 72b, and 72c and two reflectors 71s and 71t, and 72s and 72t are cascade-connected; one end of the middle IDT 71a of one longitudinal coupling resonator-type filter element 71 is connected to an unbalanced terminal 73; and one end (one bus bar) of the middle IDT 72a of the other longitudinal

coupling resonator-type filter element 72 is divided into two and the two are connected to balanced signal terminals 74 and 75, a surface acoustic wave filter 80 having the structure shown in Fig. 11 in which, regarding two sets of surface acoustic wave filter elements 81, 82, 83, and 84 having three IDTs 81a, 81b, and 81c; 82a, 82b, and 82c; 83a, 83b, and 83c; and 84a, 84b, and 84c and two reflectors 81s and 81t; 82s and 82t; 83s and 83t; and 84s and 94t cascade-connected, one end of each of the middle IDTs 81a and 83a of one surface acoustic wave filter elements 81 and 83 is connected to balanced terminals 85 and 86, and one end of each of the other surface acoustic wave filter elements of the sets is connected to an unbalanced terminal 87, and other surface acoustic wave filters cannot share the package with a surface acoustic wave filter having a balanced-to-unbalanced conversion function of another structure different in terms of the way surface acoustic wave elements are coupled.

Moreover, since the signal lines inside the package become unsymmetrical, the affect of parasitic capacitance, etc., becomes different between balanced signal terminals, and, as a result, there is a problem in that the balancing between balanced signal terminals is worsened.

In a surface acoustic wave filter in Patent Document 3, an intersection is performed by forming a balanced signal line on a piezoelectric substrate and forming an unbalanced signal line on an insulating film formed on the balanced signal line. Accordingly, the difference between the parasitic capacitance and bridge capacitance entering the two balanced signal terminals increases and the balancing cannot be fully improved.

In consideration of such factors, it is a second object of the present invention to provide a surface acoustic wave filter which is easy to share a package with a surface acoustic wave filter of another structure and in which the balancing between balanced signal terminals

is improved.

That is, the present invention is to provide a surface acoustic wave device in which characteristics can be improved.

Disclosure of Invention

The present invention provides a surface acoustic wave device having the following structure.

A surface acoustic wave device comprises a substrate; a plurality of terminals disposed on the substrate and containing at least an unbalanced terminal and two balanced terminals; and at least one surface acoustic wave element disposed between the unbalanced terminal and the balanced terminals on the substrate. In the surface acoustic wave device, different signal lines connected to the same surface acoustic wave element intersect through an insulating film.

In the above structure, the substrate may be a piezoelectric substrate in which the whole substrate is made of a piezoelectric material or a piezoelectric substrate in which a thin film of piezoelectric material (piezoelectric thin film) is formed on the main body of a substrate made of non-piezoelectric material. In the latter case, at least a piezoelectric thin film is formed in the portion of a surface acoustic wave element. A balanced signal is input to or output from a balanced terminal and an unbalanced signal is input to or output from an unbalanced terminal.

As in the above structure, when different signal lines connected to the surface acoustic wave elements intersect through an insulating film, the signal lines can be more shortened than in the case where the signal lines are set not to intersect and the restrictions on setting the signal lines can be eased.

In this way, for example, when a balanced type surface acoustic wave filter is constructed by connecting two surface acoustic wave elements using signal lines, the insertion loss can be reduced in such a way that the signal lines connecting between the surface acoustic

wave elements are shortened by narrowing the space between the two surface acoustic wave elements, without containing pads between the surface acoustic wave elements.

Furthermore, regarding the signal lines connecting between the surface acoustic wave elements and the signal lines connecting between the surface acoustic wave elements and the terminals, since the restrictions on setting the lines are eased, it becomes easy to have the package for common use.

Preferably, the insulating film is polyimide.

Since the relative dielectric constant of the polyimide is sufficiently small in comparison with the relative dielectric constant of the piezoelectric substrate, stray capacitance can be reduced.

As a preferable first mode, at least two of the surface acoustic wave elements are contained. One of the two surface acoustic wave elements (hereinafter, referred to as a first element) is connected to the unbalanced terminal and a ground terminal (hereinafter, referred to as a ground pad) for grounding with the different signal lines. At least two of the signal line (hereinafter, referred to as a signal wiring for connecting the other of the two surface acoustic wave elements (hereinafter, referred to as a second element) and the first element are formed. At least one of the signal wiring and the signal line (hereinafter, referred to as a ground wiring) for connecting the ground pad and the first element intersect through the insulating film. The ground pad is disposed outside an area enclosed by the first element, the second element, and the signal wirings.

In the related device, the ground pad is formed inside an area enclosed by the first element, the second element, and the signal wirings and the insertion loss in the passband increases. But, according to the above construction, the stray capacitance between the ground pad and the signal lines is reduced and, as a result, the insertion loss in the passband can be reduced in such a way that the

ground pad is formed outside an area enclosed by the first element, the second element, and the signal wirings.

Preferably, the first element contains three IDTs disposed so as to have the same propagation direction of a surface acoustic wave, and the unbalanced terminal and the ground pad are connected to the middle IDT. The second element contains three IDTs disposed so as to have the same propagation direction of a surface acoustic wave, and two balanced terminals are connected to the middle IDT. The IDTs on either side of the first element and the IDTs on either side of the second element are connected by the signal wirings.

According to the above structure, the insertion loss in the passband of a balanced type SAW filter in which the longitudinal coupling resonator-type SAW filter elements (first element and second element) are cascade connected can be reduced.

Preferably, two sets of the first element, the signal wirings, and the second element are formed on the substrate. The first element of each set contains three IDTs disposed so as to have the same propagation direction of a surface acoustic wave, and the unbalanced terminal and the ground pad are connected to the middle IDT. The second element of each set contains one IDT connected to one of the balanced terminals different from that in the other sets. In each set, the two signal wirings connect the IDTs on either side of the first element and the IDT of the second element. The first elements of the two sets are in opposite phase to each other.

According to the above structure, the longitudinal coupling resonator-type SAW filter (first element) connected to a balanced pad and the one-port SAW resonator (second element) are connected in series, two sets of these are connected in parallel, the longitudinal coupling resonator-type SAW filter (first element) is made to be in opposite phase, and the one-port SAW resonator (second element) is used as a trap. Thus, in a balanced type SAW filter having filter

characteristics improved, the insertion loss in the passband can be reduced.

Preferably, the ground wiring contains a first layer formed excluding the insulating film and its vicinity and a second layer formed including the insulating film and its vicinity.

According to the above-described structure, regarding the ground wiring, since two layers are put one on top of another around the insulating film, the ground residual impedance is decreased and the attenuation outside the band is improved. Furthermore, the signal wiring can be formed using only one layer; since two layers are not required to be put one on another around the insulating film, the signal wiring can be shortened; and the size can be reduced by shortening the distance between the first element and the second element.

As a preferable second mode, at least two surface acoustic wave elements connected to each other are contained. One of the two surface acoustic wave elements (hereinafter, referred to as a first surface acoustic wave element) is a longitudinal coupling resonator-type surface acoustic wave element having three IDTs disposed along the propagation direction of a surface acoustic wave, and the middle IDT out of the three IDTs is connected to the two balanced signal terminals through the two signal lines (hereinafter, referred to as first and second signal lines). The two balanced signal terminals are disposed on either side of the central axis of the substrate substantially in parallel to the direction in which the two surface acoustic wave elements are arranged. At least one of the first and second signal lines is disposed on the insulating film formed on the substrate.

In the above-described structure, when at least one of the first and second signal lines and the signal line connecting between the surface acoustic wave elements intersect, in this intersecting portion,

a three-dimensional intersection is performed through an insulating film.

According to the above-described structure, the package can be commonly used by arranging the balanced signal terminals at the same locations as in a surface acoustic wave filter of another structure different in the condition for coupling the surface acoustic wave element. Furthermore, regarding the parasitic capacitance and bridge capacitance entering each of the two balanced signal terminals, the difference between them is reduced by disposing the signal lines connected to the balanced signal terminals on an insulating film and thus, the balancing can be improved.

Preferably, the two balanced signal terminals are disposed so as to be substantially symmetrical around the central axis of the substrate.

According to the above-described structure, since the balanced signal terminals are disposed substantially in the same location as in a surface acoustic wave filter of another structure in which the balanced signal terminals are symmetrically disposed, it is excellent in common use of the package.

Preferably, the second surface acoustic wave element is disposed in the propagation direction of a surface acoustic wave and is a longitudinal coupling resonator-type surface acoustic wave filter element having three IDTs cascade-connected to the first surface acoustic wave element.

According to the above-described structure, the attenuation outside the passband can be increased.

Preferably, the second surface acoustic wave element is one or a plurality of surface acoustic wave resonator elements connected together.

According to the above-described structure, the attenuation outside the passband can be increased.

As a preferable third mode, the surface acoustic wave element is a longitudinal coupling resonator-type surface acoustic wave filter element containing three IDTs disposed along the propagation direction of a surface acoustic wave, and the middle IDT out of the three IDTs is connected to the two balanced terminals through the signal lines (hereinafter, referred to as first and second signal lines). The two balanced signal terminals are disposed on both sides of the central axis of the substrate substantially perpendicular to the propagation direction of a surface acoustic wave. At least one of the first and second signal lines is disposed on the insulating film formed on the substrate.

In the above-described structure, when at least one of the first and second signal lines intersects the signal line and the connection line connecting between the IDT and the terminals excluding the balanced terminals, in this intersecting portion, a three-dimensional intersection is performed through an insulating film.

According to the above-described structure, the package can be commonly used by arranging the balanced signal terminals at the same locations as in a surface acoustic wave filter of another structure different in the mode for coupling the surface acoustic wave elements. Furthermore, regarding the parasitic capacitance and bridge capacitance entering each of the two balanced signal terminals, the difference between them is reduced by disposing the signal lines connected to the balanced signal terminals on an insulating film and thus, the balancing can be improved.

In a surface acoustic wave device of the present invention, the characteristics can be improved. For example, in the case of the above-described first mode, the insertion loss in the passband can be reduced. Furthermore, in the case of the second and third modes, the difference of parasitic capacitance entering each balanced signal terminal is more reduced than in the structure described in Patent

Document 2 and the balancing between the balanced signal terminals is improved. Furthermore, it becomes possible to commonly use the package with a surface acoustic wave filter having a balanced-to-unbalanced conversion function of another structure shown in Fig. 10, Fig. 11, etc., and accordingly, it becomes unnecessary to produce a package for exclusive use.

Brief Description of the Drawings

Fig. 1 is a top view of a balanced type SAW filter. (Embodiment 1)

Fig. 2 is a sectional view taken on line II - II of Fig. 1. (Embodiment 1)

Fig. 3 is a top view of a balanced type SAW filter. (Embodiment 2)

Fig. 4 is a sectional view taken on line IV - IV of Fig. 3. (Embodiment 2)

Fig. 5 is a top view of a balanced type SAW filter. (Related example)

Fig. 6 shows the structure of a piezoelectric substrate. (Related example 2)

Fig. 7 is a top view of the upper portion of a package. (Related example 2)

Fig. 8 is a top view of the lower portion of a package. (Related example 2)

Fig. 9 shows the bottom surface of a package. (Related example 2)

Fig. 10 shows the structure of a surface acoustic wave filter. (Reference example 1)

Fig. 11 shows the structure of a surface acoustic wave filter. (Reference example 2)

Fig. 12 shows the structure of a surface acoustic wave filter. (Reference example 3)

Fig. 13 is a top view of a piezoelectric substrate. (Embodiment 3)

Fig. 14 is a diagram showing characteristics of a surface acoustic wave filter. (Embodiment 3)

Fig. 15 is a top view of a piezoelectric substrate. (Comparative example)

Fig. 16 is a top view of a piezoelectric substrate. (Embodiment 4)

Fig. 17 is a top view of a piezoelectric substrate. (Embodiment 5)

Fig. 18 is a top view of a piezoelectric substrate. (Reference example 1)

Fig. 19 is a top view of a piezoelectric substrate. (Reference example 2)

Fig. 20 is a bottom view of a package. (Embodiment 3)

Fig. 21 is a top view of a piezoelectric substrate. (Embodiment 6)

Fig. 22 is a top view of a piezoelectric substrate. (Related example 2)

Fig. 23 is a top view of a piezoelectric substrate. (Embodiment 7)

Reference Numerals

100 piezoelectric substrate

101 surface acoustic wave filter element (second surface acoustic wave element)

102 surface acoustic wave filter element (first surface acoustic wave element)

103, 104, and 105 IDTs

108, 109, and 110 IDTs

118 and 119 balanced signal terminals

123 and 124 signal lines

150 surface acoustic wave resonator element (second surface acoustic wave element)

250, 251, and 252 insulating films

500 piezoelectric substrate

502 surface acoustic wave filter element (surface acoustic wave element)

508, 509, and 510 IDTs

518 and 519 balanced signal terminals

523 and 524 signal lines

650 and 652 insulating films

1010 substrate

1014 and 1016 insulating films

1020 filter (first element)

1022, 1023, and 1024 IDTs

1030 filter (second element)

1032, 1033, and 1034 IDTs

1041 and 1042 wirings (signal wirings)

1048 wiring (ground wiring)

1048a, 1048b, and 1048c first layers

1048s second layer

1051 pad (unbalanced terminal

1052 and 1053 pads (balanced terminals)

1054 and 1055 ground pads

1100 substrate

1106 and 10107 insulating films

1110 filter (first element)

1114, 116, and 118 IDTs

1120 filter (first element)

1124, 126, and 128 IDTs

1130 trap (second element)

1134 IDT

1140 trap (second element)

1144 IDT

1153 wiring (ground wiring)

1153a first layer

1153s second layer

1154 wiring (ground wiring)

1154a first layer

1154s second layer

1155, 1156, 1157, and 1158 wirings (signal wirings)

1172 ground pad (ground terminal)

1173 pad (unbalanced terminal)

1174 and 1175 pads (balanced terminals)

Best Mode for Carrying Out the Invention

Hereinafter, the embodiments of the present invention are described with reference to Figs. 1 to 23.

First, embodiments 1 and 2 are described with reference to Figs. 1 to 4.

EMBODIMENT 1

A surface acoustic wave device of an embodiment 1 is described with reference to Figs. 1 and 2. Fig. 1 is a top view of a substrate 1010 contained in the surface acoustic wave device of the embodiment 1 and Fig. 2 is a sectional view taken along line II - II of Fig. 1.

The surface acoustic wave device of the embodiment 1 is an EGSM receiving band filter. For example, the input impedance is 50 Ω, the output impedance is 150 Ω, the pass frequency band is 925 to 960 MHz, and the center frequency is 942.5 MHz.

The substrate 1010 is formed of a $LiTaO_3$ single crystal piezoelectric substrate and a metal film of a fixed pattern is formed on its main surface 1012 as shown in Fig. 2. That is, a balanced-type SAW filter in which a longitudinal coupling resonator-type surface acoustic wave filter 1020 (hereinafter, referred to as a filter 1020) of a first stage and a longitudinal coupling resonator-type surface acoustic wave filter 1030 (hereinafter, referred to as a filter 1030) of a second stage are cascade-connected, a pad 51 is an unbalanced terminal, and pads 1052 and 1053 are balanced terminals is constituted. Wirings, that is, signal wirings 1041 and 1042 by which the filter 1020 as a first element and the filter 1030 as a second element are cascade-connected intersect a ground wiring 1048 connected to an IDT 1023 including an unbalanced terminal 1051 in three dimensions. The

ground wiring 1048 to the unbalanced terminal 1051 is connected to ground pads 1054 and 1055 contained in a place outside between the stages. The ground pads 1054 and 1055 are ground terminals for grounding. The filters 1020 and 1030 are disposed in parallel so that the propagation direction of the surface acoustic waves may be parallel to each other.

In detail, in the filter 1020 of the first stage, three IDTs 1022, 1023, and 1024 are disposed in line with the propagation direction of a surface acoustic wave and two reflectors 1021 and 1025 are disposed on either side of the IDTs 1022, 1023, and 1024. One electrode side of the middle IDT 1023 is connected to the pad 1051 as an unbalanced terminal through a wiring 1047. The other electrode side is connected to the ground pads 1054 and 1055 from the wirings 1040 and 1048 through wirings 1043 and 1046. The sides of one electrode of the other IDTs 1022 and 1024 are also connected to the ground pads 1054 and 1055 through wirings 1044 and 1045.

In the filter 1030 of the second stage, three IDTs 1032, 1033, and 1034 are disposed in line in the propagation direction of a surface acoustic wave and two reflectors 1031 and 1035 are disposed on either side of the IDTs 1032, 1033, and 1034.

One electrode side of the middle IDT 1033 is connected to the pads 1052 and 1053 as balanced terminals and the other electrode is made a floating electrode. The sides of one electrode of the IDTs 1032 and 1034 disposed on either side of the IDT 1033 are connected to the sides of the other electrode of the IDTs 1022 and 1024 of the filter of the first stage. The sides of the other electrode of the IDTs 1032 and 1034 are connected to the ground pads 1054 and 1055 through wirings 1043 and 1046.

Rectangular insulating films 1014 and 1016 are formed so as to cover parts of the wirings 1041 and 1042 of a signal line connecting the filters 1020 and 1030, the wiring 1048 is formed on the insulating

films 1014 and 1016, and the wirings 1041 and 1042 and the wiring 1048 intersect through the insulating films 1014 and 1016 in three dimensions.

In the measurements of the insulating films 1014 and 1016, the dimension in the transverse direction (in the extending direction of the wiring 1048) in the drawing is 50 μm, the dimension in the longitudinal direction (in the extending direction of the wirings 1041 and 1042) in the drawing is 1040 to 50 μm, and the thickness is 2 μm. The width of the lower wirings 1041 and 1042 is about 30 μm and the width of the upper wiring 1048 is 20 to 30 μm where the wirings intersect in three dimensions. The space between the filters 1020 and 1030 is 60 to 70 μm. The dimensions of the ground pads 1054 and 1055 are 100 μm × 100 μm. In the related example in which the ground pads having the same dimensions are contained between the two cascade-connected longitudinal coupling resonator-type surface acoustic wave filters, since the distance between the filters is about 200 μm, in the embodiment 1, the distance between the filter elements is shortened so as to be about one third or less than that in the related example. A photosensitive resin (polyimide, relative dielectric constant: about 2) is used for the insulating films 1014 and 1016, for example.

In the embodiment 1, when the wiring 1048 (also referred to as a ground wiring 1048) for the connection to the ground pads 1054 and 1055 and the wirings 1041 and 1042 (also referred to as signal wirings 1041 and 1042) for the connection between the filters 1020 and 1030 intersect, the intersecting area seen from the top is sufficiently small, the relative dielectric constant of the insulating films 1014 and 1016 is sufficiently small in comparison with the relative dielectric constant of the $LiTaO_3$ substrate 10 which is about 50, and the thickness of the insulating films 1014 and 1016 is sufficiently large. Accordingly, the stray capacitance can be reduced in

comparison with the structure in which two elements are cascade-connected and ground pads are disposed between stages as in the related example.

Next, the manufacturing method for the substrate 1010 is described.

First, an aluminum film pattern of the first layer is formed on the main surface 1012 of the substrate 1010 by dry etching or lift-off. The aluminum film pattern of the first layer substantially matches the final metal pattern of the IDTs, pads, wirings, etc. However, as shown in Fig. 2, regarding the wiring 1048, the pattern of the first layer is not formed in the portion where the insulating films 1014 and 1016 are formed and in its vicinity so that the insulating layers 1014 and 1016 may be disposed between the first layers 1048a, 1048b, and 1048c. The thickness of the aluminum film of the first layer is made the same as the film thickness of the IDTs 1022 to 1024 and 1032 to 1034 and, for example, the thickness in a 800 MHz band SAW filter is 300 to 400 nm and the thickness in a 2 GHz band SAW filter is 150 to 200 nm.

Next, a photosensitive resin is coated and the insulating films 1014 and 1016 are formed in the intersecting portion of the wirings 1041 and 1042 between the filters 1020 and 1030 and the ground wiring 1048 by using photolithography.

Next, a resist mask having an opening corresponding to the final metal film pattern excluding the exposed portion of the filters 1020 and 1030 and the wirings 1041 and 1042 is formed and the aluminum film pattern of the second layer is formed by using lift-off. Ti or NiCr as an adhesive layer may be formed between the aluminum of the first layer and the substrate 1010 or between the aluminum of the second layer and the aluminum of the first layer.

In this way, as shown in Fig. 2, the second layer 1048s of the wiring 1048 is put on top of the first layers 1048a, 1048b, and 1048c and connected. In the connection portion between the second layer

1048s and the first layers 1048a, 1048b, and 1048c, the connection portion is required to have a fixed area or an area larger than that required to sufficiently reduce the connection resistance between the second layer 1048s and the first layers 1048a, 1048b, and 1048c. Accordingly, in the wiring 1048, the overlapping area between the first layers 1048a, 1048b, and 1048c and the second layer 1048s is made an area of 20 μm or more per side.

It is required to connect the upper wiring (second layer) of the three-dimensional intersection to the first layer connected to the IDTs at a certain location. When the signal line for connecting the two elements is disposed on the upper side of the three-dimensional intersection, a connection portion for connecting the first layer and the second layer is needed between one element and the three-dimensional intersection and between the other element and the three-dimensional intersection. That is, it is necessary to increase the distance between the two elements in order to include not only the insulating film of the three-dimensional intersection, but also the connection portion between the first layer and the second layer.

On the other hand, when the signal lines (wirings 1041 and 1042) for connecting the two elements (filters 1020 and 1030) are disposed on the lower side of the three-dimensional intersection as in the embodiment 1, since it is not necessary to provide the connection portion between the elements and the three-dimensional intersection, the distance between the two elements can be decided by only the dimensions of the insulating film of the three-dimensional intersection.

In particular, in the embodiment 1, the middle IDT 1033 in the second stage is divided and constructed so as to cope with a balanced output (or balanced input) and no ground wiring is required in the middle IDT 1033 in the second stage. Accordingly, regarding the ground wirings between the filters 1020 and 1030, only the ground

wiring 1048 for the middle IDT 1023 in the first stage is required.

In the embodiment 1, the signal wirings 1041 and 1042 between the filters 1020 and 1030 are contained only in the first layer and the electric resistivity of the lines increases. However, the distance between the filters 1020 and 1030 is shortened and the deterioration of the insertion loss in the band can be prevented.

In the surface acoustic wave device of the embodiment 1, the stray capacitance between the signal line and the ground pads is reduced by the movement of the ground pads 1054 and 1055 from between the filters 1020 and 1030 and the insertion loss in the passband can be decreased by making the between-stage distance smaller (that is, shortening the signal wirings 1041 and 1042 between the filters 1020 and 1030).

EMBODIMENT 2

Next, a surface acoustic wave device of an embodiment 2 of the present invention is described with reference to Figs. 3 and 4. Fig. 3 is a top view of a substrate 1100 contained in the surface acoustic wave device of the embodiment 2 and Fig. 4 is a sectional view taken on line IV - IV of Fig. 3.

The surface acoustic wave device of the embodiment 2 is a device in which the substrate 1100 having a metal film of a fixed pattern formed on the main surface 1102 is housed in a package (not illustrated) and can be manufactured by the same method as in the embodiment 1. Hereinafter, the different points from the embodiment 1 are mainly described.

The surface acoustic wave device of the embodiment 2 is a DCS receiving band surface acoustic wave filter. For example, the input impedance is 50 Ω, the output impedance is 150 Ω, and the pass frequency band is 1805 to 1880 MHz.

As shown in Fig. 3, two sets of longitudinal coupling resonator-type SAW filters 1110 and 1120 (hereinafter, also referred to as filters 1110 and 1120) as first elements are connected in parallel to

a pad 1173 as an unbalanced terminal, and pads 1174 and 1175 are used as balanced terminals. One-port SAW resonators 1130 and 1140 (hereinafter, referred to as traps 1130 and 1140) as second elements are connected in series to the filters 1110 and 1120.

The two-element cascade connection in the longitudinal coupling resonator-type SAW filters as in the embodiment 1 has the advantage that high attenuation can be realized outside the passband, but it is at a disadvantage in that the insertion loss in the passband increases. As in the embodiment 2, high attenuation can be realized in the vicinity of the passband by the series connection of the one-port SAW resonators 1130 and 1140 to the longitudinal coupling resonator-type SAW filters 1110 and 1120. The one-port SAW resonators 1130 and 1140 are used as taps where an antiresonant frequency is positioned on the higher frequency side than the passband of the resonator-type SAW filters 1110 and 1120.

In detail, in the filters 1110 and 1120, three IDTs 1114, 1116, and 1118; and 1124, 1126, and 1128 are disposed in line in the propagation direction of a surface acoustic wave, and two reflectors 1112 and 1122 are disposed on both sides of the IDTs, respectively. One electrode sides of the middle IDTs 1116 and 1126 are connected to a pad 1173 as an unbalanced terminal through wirings 1151 and 1152, respectively. The other electrode sides are connected to a ground pad 1172 as a ground terminal through wirings 1153a and 1153, and 1154a and 1154. One electrode sides of the other IDTs 1114 and 1118, and 1124 and 1128 are also connected to the ground pad 1172 through wirings 1150 and 1159.

The filter 1110 is opposite in phase to the filter 1120. Furthermore, in the IDTs 1124 and 1128 of one filter 1120, the intersection is weighted for adjustment of the balancig.

In the traps 1130 and 1140, reflectors 1132 and 1142 are disposed on both sides of the IDTs 1134 and 1144. One electrode sides of the

IDTs 1134 and 1144 are connected to the other electrode side of the IDTs 1114 and 1118, and 1124 and 1128 of the filters 1110 and 1120 through wirings 1155 and 1156, and 1157 and 1158, respectively. The other electrode sides of the IDTs 1134 and 1144 are connected to pads 1174 and 1175 as balanced terminals through wirings 1160 and 1162, respectively.

The wirings 1156 and 1157 out of the wirings 1155 and 1156, and 1157 and 1158 by which the filters 1110 and 1120 are longitudinally connected to the traps 1130 and 1140 intersect the wirings 1153 and 1154 by which the ground pad 1172 disposed in the middle is connected to the filters 1110 and 1120 through insulating films 1106 and 1107 in three dimensions. Furthermore, the wirings 1151 and 1152 also intersect the wiring 1150 through insulating films 1104 and 1105.

As for the dimensions of the insulating films 1104, 1105, 1106, and 1107, the measure in the transverse direction (extending direction of the wirings 1150, 1153, and 1154) in Fig. 3 is 70 μm, the measure in the longitudinal direction (extending direction of the wirings 1151 and 1152 and perpendicular to the extending direction of the wirings 1153 and 1154) in Fig. 3 is 40 to 50 μm, and the thickness is 2 μm. The width of the lower wirings 1150, 1156, and 1157 in the three dimensional intersection is about 30 μm and the width of the upper wirings 1151, 1152, 1153, and 1154 is 20 to 30 μm. The space between the filters 1110 and 1120 and the traps 1130 and 1140 is 60 to 70 μm. The dimensions of the ground pad 1172 are 100 μm × 100 μm. In the related example where the ground pad of the same dimensions is contained between the filter and the trap, the space between the filter and the trap is about 200 μm, and, in the embodiment 2, the space between the filters 1110 and 1120 and the traps 1130 and 1140 can be made about one third or less than that in the related example.

As shown in Fig. 4, second layers 1153s and 1154s of the wirings 1153 and 1154 are formed on the insulating layers 1106 and 1107, and

the second layers 1153s and 1154s are put on the first layer 1172a of the ground pad 1172 and wirings 1153a and 1154a of only the first layer on the both sides of the insulating films1106 and 1107. The first layer is put on the second layer in an area of a 20 μm or more per side and both are connected.

Moreover, the second layer is formed in the pads 1172, 1173, 1174, and 1175, the middle portion of the wiring 1150, and the wirings 1151, 1152, 1153, 1154, 1159, 1160, and 1162.

In the embodiment 2, the three dimensional wiring is performed between the filters 1110 and 1120 and the traps 1130 and 1140, but the same effect as in the embodiment 1 can be obtained. That is, since the space between the two elements of the filters 1110 and 1120 and the traps 1130 and 1140 can be determined by only the dimensions of the insulating films 1106 and 1107 for three dimensional intersection, the space can be made small.

Since no ground wiring is necessary in the traps 1130 and 1140, only one ground wiring is required between the two elements for grounding the filters 1110 and 1120. Even if the wirings 1155 and 1156, and 1157 and 1158 between the two elements are performed by only the first layer and the electric resistivity of the lines increases, since the distance between the two elements is shortened, the deterioration of the insertion loss in the band can be prevented.

Next, embodiments 3 to 7 are described with reference to Figs. 12 to 21 and Fig. 23. Moreover, in the drawings, the same reference numerals are given the portions of the same structure.

EMBODIMENT 3

A surface acoustic wave filter of an embodiment 3 is described with reference to Figs. 12 to 19 and Fig. 22. The surface acoustic wave filter of the embodiment 3 contains a balanced-to-unbalanced conversion function. Here, an EGSM (extended global system for mobile communications) receiving filter in which the impedance of an

unbalanced signal terminal is 50 Ω and the impedance of a balanced signal terminal is 100 Ω is described as an example.

First, the structure of the embodiment 3 is described with reference to Figs. 12 and 13.

In the surface acoustic wave filter of the embodiment 3, two longitudinal coupling resonator-type surface acoustic wave filter elements (hereinafter, referred to as filter elements) 101 and 102 are formed on a piezoelectric substrate 100 and cascade connected. A $LiTaO_3$ 40 ± 5° Y-cut X-propagation substrate is used in the piezoelectric substrate 100 and the filter elements 101 and 102 are formed by using aluminum electrodes.

As the basic structure is schematically shown in Fig. 12, one filter element 101 contains three IDTs 103, 104, and 105 and two reflectors 106 and 107 disposed along the propagation direction of a surface acoustic wave. The other IDTs 103 and 105 are formed so as to sandwich the middle IDT 104 and the reflectors 106 and 107 are formed on both sides of them. One end of the middle IDT 104 is connected to an unbalanced signal terminal 117 by a signal line 122.

In the same way, the other filter element 102 also contains three IDTs 108, 109, and 110 and two reflectors 111 and 112 disposed along the propagation direction of a surface acoustic wave. The other IDTs 108 and 110 are formed so as to sandwich the middle IDT 109 and the reflectors 111 and 112 are formed on both sides of them. Both ends of the middle IDT 109 are connected to balanced signal terminals 118 and 119 by signal lines 123 and 124, respectively.

The two filter elements 101 and 102 are cascade connected. That is, one end of the IDTs 103 and 105 each of the filter element 101 is connected to one end of the IDTs 108 and 110 each of the other element 102 by signal lines 120 and 121, respectively. The other end of the IDTs 103 and 105 each of the filter element 101 and the other end of the IDTs 108 and 110 each of the other filter element 102 are grounded,

respectively. Moreover, even if the other ends are connected to each other in the same way as in one ends, instead of connection to the ground, there is no problem in operation.

The direction of the IDTs 103, 104, 105, 108, 109, and 110 each is adjusted so that the phase of an electric signal transmitted on a signal line 120 connected between the IDTs 103 and 108 may be about 180 degrees different from the phase of an electric signal transmitted on a signal line 121 connected between the IDTs 105 and 110. Thus, excellent amplitude balancing and phase balancing as a surface acoustic wave filter can be obtained.

In the portions shown by reference numerals 113 to 116 (hereinafter, referred to as narrow-pitched electrode finger portions) in Fig. 12, that is, in the portions between the IDTs 103 and 104 and between the IDTs 104 and 105 of one filter element 101 and between the IDTs 108 and 109 and between the IDTs 109 and 110 of the other filter element 102, the pitch of a few neighboring electrode fingers (width of an electrode finger and space between electrode fingers) is made smaller than that in the other portion of the IDTs 103, 104, 105, 108, 109, and 110. Moreover, in Fig. 12, for simplicity, the number of electrode fingers is illustrated so as to be less than the actual ones. A broad bandpass filter can be obtained in such a way that the discontinuity at the portions where IDTs neighbor each other is reduced to the utmost by containing such narrow-pitched electrode finger portions 113 to 116 and that the space between the IDTs 103, 104, 105, 108, 109, and 110 is adjusted.

Fig. 13 shows the actual layout on a piezoelectric substrate 100. In Fig. 13, the oblique line portion having a narrow space is an electrode pattern (hereinafter, referred to as a first layer pattern) formed in a first photolithographic process. The oblique line portion having a wide space is an electrode pattern (hereinafter, referred to as a second layer pattern) formed in a second photolithographic

process. The portions having no oblique line 250, 251, and 252 are an insulating film formed by using a resin having a low dielectric constant, etc. before the second layer pattern has been formed. In Fig. 13, for brevity, the first layer pattern and the second layer pattern are illustrated so as to be in contact with each other, but actually, at least one of the first layer pattern and the second layer pattern is formed so as to be larger than the illustration in the vicinity of the location where both are in contact with each other and the second layer pattern is put on the first layer pattern to connect both.

The unbalanced terminal 117 is disposed in the upper middle portion of the piezoelectric substrate 100 in Fig. 13. The balanced signal terminals 118 and 119 are disposed in the lower left and right portions of the piezoelectric substrate 100 in Fig. 13, respectively. Ground terminals 201 and 202 are disposed in the upper left and right portions of the piezoelectric substrate 100 in Fig. 13, respectively. That is, the balanced signal terminals 118 and 119 are disposed so as to be symmetrical around the imaginary central axis of the piezoelectric substrate 100.

One terminal of the middle IDT 104 of one filter element 101 is connected to the unbalanced terminal 117 and the other terminal is connected to the ground terminal 202. One end of the IDTs 103 and 105 each on both sides of one filter element 101 is connected to the ground terminals 201 and 202, respectively, and the other end is connected to one end of the IDTs 108 and 110 each of the other filter element 102 through the signal lines 120 and 121, respectively. The connection line for connecting the other end of the middle IDT 104 to the ground terminal 202 intersects the signal line 201 in three dimensions through an insulating film 251 formed on the signal line 121 for connecting between the IDTs 105 and 110 in the portion shown by reference numeral 203.

The other end of the IDT 108 of the other filter element 102 is connected to the ground terminal 201 through the reflectors 111 and 106. That is, the other end of the IDT 108 and the reflector 111 are connected by a connection line 130, the reflectors 106 and 110 are connected by a connection line 131, and the reflector 106 and the ground terminal 201 are connected. The other end of the IDT 110 is connected to the ground terminal 202. One end of the middle IDT 109 is connected to one balanced signal terminal 118 by a signal line 123. Most of the signal line 123 is formed on an insulating film 250. The signal line 123 intersects the connection line for connecting the reflectors 106 and 111 in three dimensions through the insulating film 250 in the portion shown by reference numeral 204 and intersects the signal line 120 for connecting between the IDTs 103 and 108 in three dimensions through the insulating film 250 in the portion shown by reference numeral 205. The other end of the IDT 109 is connected to the other balanced signal terminal 119 by a signal line 124. An insulating film 252 is formed between the signal line 124 and the substrate 100 and the symmetry between the balanced signal terminals is maintained.

Next, the method for forming each pattern on the substrate 100 is described.

First, an aluminum film pattern of a first layer is formed on the substrate 100 by a dry etching method or a lift-off method. The aluminum film pattern of the first layer contains the IDTs 103, 104, and 105; 108, 109, and 110, the reflectors 106 and 107; and 111 and 112, the signal lines 120 and 121, and the connection lines 130 and 131. The thickness the aluminum film of the first layer is the same in the IDTs 103, 104, and 105; and 108, 109, and 110.

Next, a photosensitive resin is coated and the insulating films 250, 251, and 252 are formed by using a photolithography method. Polyimide (relative dielectric constant: 2) is used as a

photosensitive resin, for example. In this case, since the relative dielectric constant is sufficiently small in comparison with the relative dielectric constant of about 50 of the $LiTaO_3$ substrate 100, when the signal lines 123 and 124 connected to the balanced signal terminals 118 and 119 are formed on the insulating films 250 and 251, the stray capacitance can be reduced in comparison with the case where a signal line connected to a balanced signal terminal is formed directly on a substrate.

Next, a resist mask having an opening corresponding to the second layer pattern is formed and an aluminum film pattern of the second layer is formed by using a lift-off method.

Moreover, Ti or NiCr as an adhesive layer may be formed between the aluminum film of the first layer and the substrate 100 or between the aluminum film of the second layer and the aluminum film of the first layer.

In Fig. 20, the layout of external terminals 401 to 405 on the bottom surface of a package for the surface acoustic wave filter of the embodiment 3 is shown. In the drawing, the upper middle external terminal 401 is an unbalanced terminal and is connected to the terminal 117 in Figs. 12 and 13. The external terminals 402 and 403 in the lower right and lower left corner portions are balanced signal terminals and connected to the terminals 118 and 119 in Figs. 12 and 13, respectively. The external terminals 404 and 405 in the middle portions are ground terminals.

In the package, as shown in Figs. 18 and 19, surface acoustic wave filter element chips having a balanced-to-unbalanced conversion function of other structures in which surface acoustic wave elements 71 and 72, and 81 to 84 are formed on piezoelectric substrates 70 and 80 of the same size as the piezoelectric substrate 100 can be housed. Fig. 18 corresponds to the structure in Fig. 10 and Fig. 19 corresponds to the structure in Fig. 11. In the surface acoustic wave

filters having a balanced to unbalanced conversion function of the other structures, in the same way as the piezoelectric substrate 100 of the embodiment 3, unbalanced terminals 73 and 87 are disposed in the upper middle portion of the piezoelectric substrates 70 and 80 in the drawings, balanced signal terminals 74 and 75, and 86 and 85 are disposed in the lower left and right portions in the drawings, and the ground terminals 76 and 77, 88 and 89 are disposed in the upper left and right portions in the drawings.

Accordingly, the surface acoustic wave filter of the embodiment 3 and the surface acoustic wave filters having a balanced-to-unbalanced conversion function of the other structures as shown in Figs. 18 and 19 can have the package for common use.

Moreover, in Figs. 18 and 19, the first layer pattern, the second layer pattern, and the insulating film pattern are illustrated in the same way as in Fig. 13. In Fig. 18, the signal lines between the IDTs 71b and 72b and between the IDTs 71c and 72c and the connection line for connecting between the IDT 71a and the second terminals 76 and 77 intersect in three dimensions through insulating films 78 and 79. In Fig. 19, the signal lines for connecting between the IDTs 84a and 82a and the terminal 87 and the connection lines for connecting between the IDTs 84b an d82c and the terminals 88 and 89 intersect in three dimensions through insulating films 90 and 91, and the signal lines for connecting between the IDTs 83a and 81a and the terminals 86 and 85 and the connection lines for connecting between the IDTs 83b and 81c and the terminals 88 and 89 intersect in three dimensions through insulating films 92 and 93.

Next, one example of the designing of the surface acoustic wave filter elements 101 and 102 is given. When the wavelength determined by the pitch of electrode fingers where the pitch is not narrowed except for the narrow-pitched electrode finger portions 113 to 116 is represented by λ_I, the following relation can be obtained.

Cross width: 48.1 λ_I

Number of electrode fingers of filter element 101 (in the order of IDTs 103, 104, and 105): 28(6)/(6)24(6)/(6)28 (number of narrow-pitched electrode fingers represented by the number in the parentheses)

Number of electrode fingers of filter element 102 (in the order of IDTs 108, 109, and 110): 28(6)/(3)24(3)/(6) 28 (number of narrow-pitched electrode fingers represented by the number in the parentheses)

Number of reflectors: 80

Metallization ratio: 0.70

Electrode film thickness: 0.080 λ_I

Fig. 14 shows the relation between the frequency and common-mode attenuation characteristics of the above design example (embodiment 3). The common-mode attenuation characteristics show the balancing between balanced signal terminals, and, the more the attenuation increases, the better the balancing between balanced signal terminals becomes.

In Fig. 14, as a comparative example, the relation between the frequency and common-mode attenuation characteristics in the case where an extra wiring for balanced signal terminals are contained inside a package as in Patent Document 2 and the layout of the terminals on the bottom surface of the package is made the same as in Fig. 20 are shown. The layout on the piezoelectric substrate of the comparative example is shown in Fig. 15. The specification of the filter elements 101 and 102 is the same as that of the above design example (embodiment 3). In Fig. 15 showing the layout on a piezoelectric substrate 300, an unbalanced signal terminal 117' is disposed in the upper middle portion, a balanced signal terminal 118' is disposed on the slightly right side from the middle, and a balanced signal terminal 119' is disposed on the lower right portion. A ground terminal 301 is disposed in the upper left portion, a ground terminal

302 is disposed in the upper right portion, a ground terminal 303 is disposed on the slightly left side from the middle, and a ground terminal 304 is disposed in the lower left portion.

The passband of the EGSM receiving filter is 925 to 960 MHz. In Fig. 14, when the largest common-mode attenuation is compared in the frequency band, although the common-mode attenuation is about 24.0 dB in the comparative example, the common mode attenuation is about 27.5 dB in the embodiment and, as a result, the common mode attenuation improves by about 3.5 dB in comparison with the comparative example.

Regarding main causes why such an effect can be obtained, for one thing, since the extra wiring connected to the balanced signal terminals is not made unsymmetrical different from in the comparative example, the difference of the affect of parasitic capacitance, etc., is eliminated, and, for another thing, since the signal lines 123 and 124 for connecting between the IDTs and the balanced signal terminals on the piezoelectric substrate are provided on an insulating film pattern made of a resin of a low dielectric constant, even if the length of the signal lines 123 and 124 is different from each other on the piezoelectric substrate, it is considered that the difference of the parasitic capacitance entering each balanced terminal is small.

As is described above, according to the embodiment 3, when the terminals of the middle IDT in the three IDTs in a longitudinal coupling resonator-type surface acoustic wave filter having three IDTs are connected to balanced signal terminals, respectively, in the surface acoustic wave filter having a balanced to unbalanced conversion function, a filter having an excellent balancing between the balanced signal terminals can be obtained in comparison with the related method. Furthermore, the above surface acoustic wave filter and a surface acoustic wave filter having a balanced to unbalanced conversion function of another structure can share the package.

Next, other embodiments 4 to 7 are described. In the embodiments

4 to 7, the same effect as in the embodiment 3 can be obtained. Hereinafter, different points from the embodiment 3 are mainly described.

EMBODIMENT 4

The signal lines 123 and 124 are formed on the insulating films 250 and 251 in the embodiment 3, but, in the embodiment 4, as shown in Fig. 16, only the longer signal line 123 is contained on the insulating film 250.

EMBODIMENT 5

As shown in Fig. 17, the connecting method between the IDT 108 and the ground terminal is different from that in the embodiment 3. That is, there is no connecting line for connecting between the IDT 108 and the reflector 111, between the reflectors 106 and 111, and between the reflector 106 and the ground terminal 201. Instead, for connecting to the ground terminal 202, a connection line 132 for connecting to the IDT 108 is formed by the first layer pattern. The connection line 132 is connected to a connection line of the second layer pattern for connecting between the IDT 110 and the ground terminal 202. The insulating film 252 is formed on the connection line 132 and intersects the signal line 124 for connecting between the middle IDT 109 and a balanced signal terminal 119 in three dimensions.

EMBODIMENT 6

As shown in Fig. 21, a surface acoustic wave resonator element (hereinafter, referred to as a resonator element) 150 is connected in series to the filter element 102. Also in this case, the attenuation outside the passband can be increased in the same way as in the embodiments 3 to 5 where the two longitudinal coupling resonator-type surface acoustic wave filter elements are cascade connected.

In the resonator element 150, reflectors 152 and 153 are disposed on both sides of an IDT 151. One end of the IDT 151 is connected to an unbalanced signal terminal 117 and the other end is connected to

one ends of the IDTs 108 and 110 of the filter element 102 by signal lines 120' and 121'.

The pattern of the first layer contains the filter element 102, the resonator element 150, the signal lines 120' and 121', the connection line 130 between the IDT and the reflector 111, and a connection line 131' extending from the reflector 111 to the middle on the side of the resonator element 150. The connection line 131' extending to the middle on the side of the resonator element 150 is connected to the ground terminal 201 by the connection line of the second layer pattern. The signal line 123 for connecting between the IDT 109 of the filter element 102 and the balanced terminal 118 intersects the signal line 120' and the connection line 131' in three dimensions through the insulating film 250.

In the resonator element 150, one end of the IDT 151 is connected to the ground terminal 201 or 202, the other end connected to the filter 102 is connected to the unbalanced terminal 117 by the signal lines 120' and 121', and the resonator element 105 may be connected in parallel to the filter element 102.

Furthermore, in the resonator 150, a plurality of resonator elements may be connected in series or in parallel.

EMBODIMENT 7

As shown in Fig. 23, only one filter element 502 is disposed on a piezoelectric substrate 500. Also in this case, a filter having an excellent balancing between balanced signal terminals 518 and 519 can be obtained in comparison with the related method in the same way as in the embodiments 3 to 6. Furthermore, the filter and a surface acoustic wave filter having a balanced to unbalanced conversion function of another structure can have the package for common use.

The filter element 502 contains reflectors 511 and 512 on both sides of three IDTs 508, 509, and 510. Out of the IDTs 508 and 510 on both sides, one end of one IDT 508 is connected to a signal line 520'

and one end of the other IDT 510 is connected to a signal line 521'. The signal lines 520' and 521' are connected to an unbalanced terminal 517 by a connection line of the second layer pattern.

The pattern of the first layer contains the filter element 502, the signal lines 520' and 521', and a connection line 530 for connecting between the other end of the IDT 508 and the reflector 511. A connection line 531' extending to the middle from the reflector 511 is connected to a ground terminal 601 by the connection line of the second layer pattern. The other end of the IDT 510 is connected to a ground terminal 602 by the connection line of the second layer pattern. A signal line 523 for connecting between one end of the IDT 509 of the filter element 502 and one balanced terminal 518 intersects the signal line 520' and the connection line 531' in three dimensions through an insulating film 650. An insulating film 652 is also formed between a signal line 524 for connecting between the other end of the IDT 509 of the filter element 502 and the other balanced terminal 519 and the piezoelectric substrate 500.

As describe above, in the surface acoustic wave filter of the embodiments 3 to 7, since the layout of each terminal (bump) formed on the piezoelectric substrate can be made the same as each terminal (bump) in the element chip of a surface acoustic wave filter of another structure, the above surface acoustic wave filter and the surface acoustic wave filter of another structure can have the package for common use.

Furthermore, since the difference by route between signal lines in an element chip can be substantially reduced by forming signal lines connected to balanced signal terminals on an insulating film pattern formed on a piezoelectric substrate, balancing can be improved without providing the route difference in a package.

According to the embodiments 1 to 7, characteristics of a surface acoustic wave device can be improved.

Moreover, the present invention is not limited to the above-described embodiments, but various modifications can be performed.

For example, except for $LiTaO_3$, a single crystal substrate of quartz, $LiNbO_3$, etc., can be used as a substrate. Furthermore, the present invention can be applied to a surface acoustic wave device using a piezoelectric thin film of ZnO, AlN, etc.

For example, although a 40 ± 5°Y-cut X-propagation $LiTaO_3$ substrate is used in the embodiments 3 to 7, in the present invention, the substrate is not limited to, but the same effect can be obtained by using a substrate of 64 to 72° Y-cut X-propagation $LiNbO_3$, 41°Y-cut X-propagation $LiNbO_3$, etc.

Furthermore, the present invention can be applied to not only a surface acoustic wave filter of a structure having a balanced-to-unbalanced conversion function, but also a surface acoustic wave filter of a structure having a balanced-to-balanced conversion function.